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PATENT DATA AS A TOOL TO MONITOR S&T PORTFOLIOS

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Patent data as a tool to monitor S&T portfolios

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0. Abstract

This article deals with the use of patent data to monitor science and technology (S&T) portfolios. S&T portfolios have become central tools to examine and to monitor the vitality of both institutions and regions in the innovation game that underpins their economic growth and development. Those portfolios have to be monitored not only at the intra-organisational level, but also at the inter-organizational level and at the levels of specific systems of innovation. Therefore, the development of appropriate, easy-to-use and transparant, benchmark indicators to assess the strengths and weaknesses of organizational S&T portfolios is tantamount. In this paper, we report the construction of such a benchmark indicator and we assess its usefulness by applying it to the European Patent Database.

I. Monitoring S&T Portfolios

Portfolio management in science and technology is not new. Ever since the development of the concept of technological S-curves many years ago (see for example: Martino (1983), Girifalco (1991), Porter et al. (1991), Roussel et al. (1991) or Floyd (1997)), companies have developed methods to monitor and to assess the potential and the relative quality of their science and technology investments. The concept of an S-curve pointed to the explicit risks and uncertainties involved in developing new technological capabilities and applying them towards the fulfillment of product-market needs. They also provided an attempt to extrapolate the speed at which new technological trajectories would diffuse and become common technological practice (Sahal, 1981). As most companies manage a myriad of projects attempting at major as well as minor improvements of their current S&T base, it became obvious that S-curves were just one criterion relevant to assess the vitality of a corporate S&T

portfolio. Risk-reward criteria as well as indicators of competitive dynamics such as S&T positions versus those of competitors, became standard concepts. Those analyses showed that not all S&T endeavours could be considered equal. Some were indeed more fundamental than others. Abernathy and Clark (1985) were amongst the first to discern different types of S&T efforts within a company. Some of those efforts would indeed disrupt the technological competencies of the company in its sector, while others would just enhance those competencies in a rather incremental manner. Along a second dimension, they stated that a company's S&T efforts might destroy or enhance existing market and distribution relationships.

Combining the market and technology dimensions, they constructed a two-by-two frame model assessing the transilience, or impact, of various types of S&T efforts. They coined them: regular (enhancing both the existing technology and market competence of the company), niche (enhancing the existing technology competence but destroying the market competence), revolutionary (destroying the technology competence, but enhancing the market competence) and finally, architectural (destroying both the existing technology and market competence of the company). The resulting "transilience map," proved to be a first tool to map and to assess a company's S&T portfolio. The central units of analysis in this assessment became the types of product-related S&T projects a company was undertaking in its R&D departments.

The "transilience map," which was first published in 1985, marked the onset of a wide array of scholarly efforts aimed at understanding and developing methods and tools to assess and manage the multiple S&T projects within a company's boundaries. As project management techniques did not suffice any longer, multi-project management techniques were developed. The S&T portfolio became both the method and the tool to handle the complexity of this multi-project environment (e.g. Roussel et al. (1991), Wheelwright and Clark (1992), Floyd (1997), Meyer and Lehnerd (1997), Cooper et al. (1997a&b)). Typical S&T portfolio management at the company level includes criteria such as assessing and mapping:

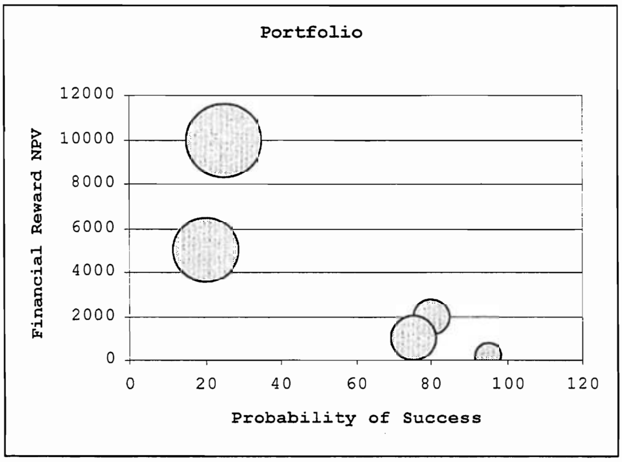
- the degree of technological maturity of the various S&T projects in the portfolio (typically according to such values as "embryonic," "growing," and "mature," as described in Foster (1986) or Roussel et al. (1991));

- the market and financial "attractiveness" of the S&T projects being proposed or executed (Wheelwright and Clark (1992), Roussel et al. (1992), Brown and Eisenhardt (1995));
- the risks involved with the various S&T projects, typically along dimensions as technological risks, commercial risks and increasingly, operational risks (see Roussel et al. (1991));
- the potential rewards of the various S&T projects, using standard financial techniques as Net Present Value calculations or real options modelling (Jägle (1999), Perlitz et al. (1999), Angelis (2000), Boer (2000),McGrath and MacMillan (2000);
- the competitive position, focusing on strengths and weaknesses, the company has achieved in the various S&T projects proposed or selected viz. its main competitors (Meyer and Lehnerd (1997), Cooper et al. (1997a&b));
- the presence or lack of competencies with respect to the definition, implementation and timely execution of the various S&T projects in the portfolio (Nonaka and Takeuchi (1995), Bone and Saxon (2000), Cooper et al. (2000)).

The next step in these portfolio management approaches typically is an analytical one. The various criteria just listed are subjected to both univariate and multivariate analyses. The multivariate analyses allow for screening the variance and the covariance within the portfolio, on the different dimensions and criteria utilised. A typical example of a portfolio with five S&T projects is presented in Figure 1. This map shows the distribution of the five projects along two dimensions: probability of project success (X-axis) and financial return as measured via an NPV-calculation (Y-axis). The sizes of the bubbles in the bubble chart represent the respective project budgets. Typically, those maps are now subjected to various analyses and interpretations.

The univariate analysis will usually list and rank the various projects according to their absolute scores on the different criteria used. It is indeed a simple, first-order statistical frequency analysis. The second step will then be to look at the variance accross the different projects. Here decision-makers want to address questions as: what is the risk-profile we are willing to tolerate for our company within a given portfolio of projects? Finally, one is not only interested in distributions and variances, but also in correlation and covariance. In other words: to what extent are the different projects independent of one another on the various dimensions that have been used to analyze the portfolio. Do there exist important spillovers between the various projects, or not? Spillovers can be determined in terms of technical spillovers as well as organizational or market spillovers.

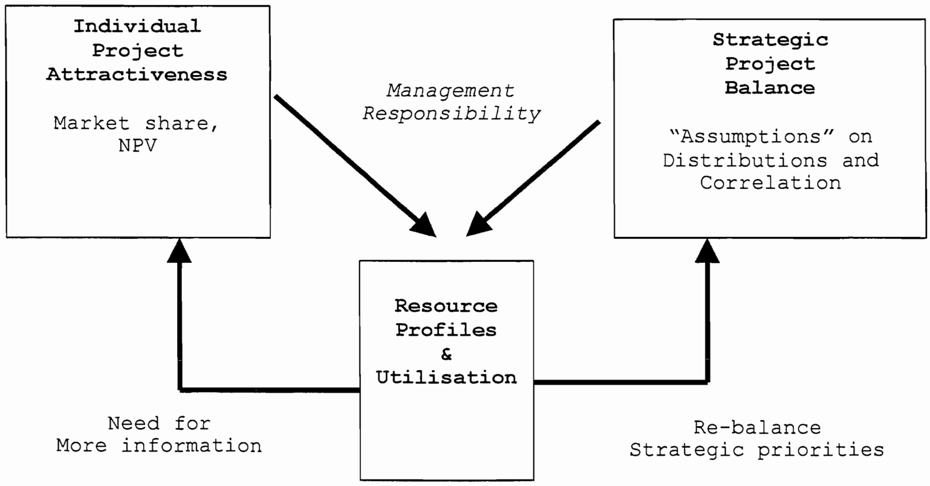
Figure 1: Portfolio Map with Five S&T Projects



Finally, the criteria and their analysis are embedded in a decision-making framework that attempts at synthesis. In other words, the end result should be a selection of S&T projects that can both sustain and rejuvenate the company's competitive position. This synthesis typically is the outcome of a triangulation process that balances (1) the attractiveness of the individual projects against (2) the spillovers and inter-project synergies to be had, taking into account (3) the resource profile availability at the company.

In Figure 2, a graphical representation of this decision-synthesis is provided. It points to the fact that portfolio selection, in the end, boils down to an iterative process of triangulating and balancing the three cornerstones just described. This is an exercise requiring both top-down and bottom-up interactions. The top-down interactions are needed to legitimate and to institutionalize. The bottom-up interactions are required to create and to build momentum.

Figure 2: The S&T Decision-Making Process



II. Stretching the S&T portfolio beyond company boundaries

The concept of S&T portfolios as described above need not be confined to intra-company decision-making. Portfolio assessment and mapping can happen at other levels of analysis as well. More specifically, the tool can be useful to monitor and to assess the performance of "systems of innovation" as well. Systems of innovation have been defined at various levels of analysis. Recently, regional as well as national systems of innovation have received ample attention (Dosi et al. (1989), Antonelli (1995)) in unravelling the dynamics of economic growth and development.

A system of innovation is the set of supportive arrangements, actors and their interactions that account for the innovation potential and capability of a region or nation. It is obvious that systems of innovation can be benchmarked against one another. The European RITTS-projects have offered opportunities for benchmarking the strengths and weaknesses of regional innovation systems (Nauwelaers, 2000). Forty

European regions have been studied as to their innovation potential and achievements. The roles and contributions of various actors in each of the regions have been assessed and documented.

Input indicators, like R&D personnel and R&D expenditures, have for sure figured on the agenda of many regional and national benchmark comparisons. However, output-oriented indicators like publications and patents (see: Debackere et al. (1999) or Luwel et al. (1999)) may have received still more attention. Output-oriented indicators are well-suited to assist in monitoring the strength and the vitality of a nation or region's S&T portfolio. Just as a company's S&T portfolio allows it to benchmark the strengths and weaknesses of its various S&T projects, so can a region's S&T portfolio allow for a comparison of the strengths and weaknesses of its various S&T actors. As a consequence, substituting actors for projects enables one to stretch the boundaries of portfolio tool utilisation from companies to regions. This is the aim of the remainder of this article: applying the concept of S&T portfolios to a benchmark study on the technological vitality or fitness of various actors within a regional system of innovation.

When applying the concept of an S&T portfolio benchmark to this level of analysis, it is important to design a transparant and consistent set of measures that are robust and allow for straightforward replication across various levels of analysis relevant to a regional system of innovation. Starting from the European Patent Database and applying the concept of the Relative Specialization Index (Balassa, 1961), we have developed such a benchmark tool.

III. Patents as a source of data to benchmark S&T portfolios

Patent data have been widely used in many studies (Griliches (1984), (1990), Schmoch et al. (1992)). Next to patent count data, it is obvious that patent documents, because of the legal "reporting" requirements, provide the researcher with a wealth of information that can be used for various types of analyses and research questions. For instance, typical patent documents contain the names and the addresses of the inventors and their applicants, as well as references to other scientific and technological documents. This information can be easily used to map progress and collaboration in technological fields as well as to assess the vitality of various organizations (firms as well as universities) in a particular field of technological development or in a particular system of innovation. Scholars like Francis Narin (1987, 1988 & 1997) have been extremely prolific in using patent data as a source of data yielding insights beyond the "mere" number counts and citation analyses. Two major sources of patent data are the European Patent Office (EPO) databases and the databases by the U.S. Patent and Trademark Office (USPTO).

Compared to the USPTO data, EPO data allow to disentangle in detail patent applications and patent grants. Indeed, in the U.S. system, patents are only listed in the USPTO databases once they have been granted. In the European system, this is not the case. Eighteen months after filing the patent, the full document is disclosed, regardless whether it has been granted or not. This difference in procedure stems from a different emphasis in patent philosophy. In the U.S. system, patent protection aims at safeguarding the rights of the inventor. The European system targets the timely diffusion of new technological information so as to stimulate the rate of technological progress.

Of course, not all patents filed are eventually granted. There are two major reasons for this difference. The first one is obvious. Whenever the patent request does not live up to the expectations of newness and inventiveness as stated in the many patent conventions that exist, the patent will not be granted.

A second explanation is more strategic in nature. We already discussed the rising importance of patent portfolios in the global competitive arena (Debackere et al., 1999). Just as patent portfolios may impede entry into specific product-markets and curtail international expansion strategies of competitors, filing for patents without having the intention to pursue the complete patent application trajectory may be part of a pre-emptive strategy. Indeed, when filing for a European patent, the applicant knows in advance that the application will be published eighteen months later, and hence from that point in time onwards, belong to the public domain. By doing so, the applicant may intentionally pre-empt others from staking claims to a similar invention. Thus, the European system with its publication rules based on filed patents instead of on granted patents, may support companies' strategic intent to pre-empt.

Since patents differ greatly in quality (see for instance Trajtenberg, 1990), scholars have since long sought to assess the value of individual patents. Three approaches have been subject to extensive research and have acquired a status of being valid measures as it comes to assessing patent quality. They are: (1) analyzing the citation patterns to specific patents, (2) studying the extent to which patent renewal fees are paid, and (3) examining the geographic scope of the patent protection requested. In this respect, the lack of citation information in the regular EPO data is unfortunate. The existence of the REFI database, which lists the references cited in the prior art search reports, can remidy this lack of information in the regular EPO databases to a certain extent, though.

For the construction of a transparant and easy-to-use benchmark map, only patent count data are used. Both patent applications and patent grants have been considered. Patent applications are considered to be closer to the input side of technology creation (serving as a proxy measure of the creation of new technologies). Patent grants are considered to be closer to the output end of the technology creation process (serving as a proxy for the exploitation of results of technological creativity).

On a total of about 750,000 patent applications available in the volume 1997/001 of Espace Bulletin, covering the period December 1978 till December 1996, 9537 patent applications have a Belgian applicant and/or inventor. Patent data have been assigned to the different Belgian regions on the basis of the addresses of the applicants and/or inventors. Given our aim to benchmark regional S&T positions, this was a necessary step in our analysis. Belgium consists of three different regions: Flanders, Wallonia and Brussels. Flanders located in the North of Belgium is the largest region, representing 60 % of Belgian GDP (in 1992). Slightly over 67% of all Belgian patent applications have a Flemish applicant and/or inventor. On average, about 47% of all EPO patents applied for are eventually granted. This average holds for the Belgian case as well as for the total EPO database.

The patent database was further extended with additional layers of data. Patent data are connected to economic data, to further assess the technological and the economic position of Belgium and Flanders. These data layers included VAT data on production statistics and export statistics, as well as data on the structure of the companies holding the patents (independent or part of multinational corporate structures). Previous analyses (reported in Debackere et al., 1999) have pointed to the overwhelming importance and presence of twenty companies in the total Belgian and Flemish patent portfolio. These companies, which account for about 63% of all Flemish EPO-patents, will be used as the empirical basis for the development of the benchmark methodology.

IV. Construction a patent-based S&T portfolio benchmark

In order to develop the benchmark method, we use a "Relative Specialization" measure as first developed by Balassa (1961), but which is now adapted to measure the Relative Specialization Index (RSI) of organizational entities in specific technological areas. The technological areas are derived using the IPC-codes as a classification scheme.

RSIij (Relative Specialty Index of organization j in technological area i)

$$= \Sigma_i \Sigma_j (Pij/Pj) \ / \ \Sigma_i \ (Pi/P)$$

with

Pij: number of patents of organization j in area i
Pj: number of patents of organization j in all areas
Pi: number of patents of all organizations in area i
P: number of patents of all organizations in all areas

RSIij compares the share of EPO patents held by an organizational entity in a certain technology area (operationalized via IPC-codes), with the share of all other entities in the same area. We now apply this index in the following manner.

Step 1

For every company or organizational entity (further referred to as the "target company") that needs to be benchmarked against a benchmark control group, we calculate the following weighted

Relative Specialization Index for the complete portfolio of IPC-domains in which the company is active:

Portfolio Specialization Index of Target Company i = PSI_i = $\Sigma_j\ w_j\ RSI_j$

with j = 1 … N the number of IPC-classes in which target company i is active

with RSI_j the Relative Technological Specialization Index of target company i in IPC-class j (see formula described above)

with w_j the relative weight of IPC-class j in the total patent portfolio of target company i, thus w_j is the fraction of the patent total of i in IPC-class j

Step 2

For the purpose of the analyses reported in the construction of the benchmark map, we have selected a benchmark control group of 665 EPO-companies against which the target companies in Flanders are to be compared. These 665 EPO-companies are all companies having a cumulative number of more than 50 granted EPO-patents for the period 1978-1996. Of course, this benchmark group could be constituted in a completely different manner as well. We created the benchmark group for purposes of developing and illustrating the benchmark map.

Once the benchmark group has been constituted, we can now calculate the following indices. For each of the 665 EPO-companies, we first select all IPC-classes which overlap with the IPC-classes in which a Flemish target company is active. The total summated set of patents in the overlapping IPC-classes now becomes the denominator for further comparisons with the Flemish target company. Each benchmark company now has a Relative Specialization Index for each of the overlapping IPC-classes.

However, the benchmark companies can also be active in IPC-classes that differ from the ones that overlap with their Flemish target companies. In other words, there exist overlap and non-overlap IPC-classes for the benchmark companies. In addition, there exist benchmark companies that do not show any overlap, but that nevertheless have developed strong positions in other IPC-classes. We can demonstrate this phenomenon as follows.

Assume a Flemish target company is active across five different IPC-classes:

AD	**BC**	**GG**	**HY**	**KL**

Assume an at random chosen benchmark EPO-company (in our example, 1 out of 665) is active in 12 IPC-classes, five of which are overlap classes with the Flemish target company:

AA	AB	**AD**	**BC**	**GG**	**HY**	**KL**	MM	PO	VG	WS	YH

Based on this IPC-class sequencing information, we now compute two new Portfolio Specialization Indices for each company in the benchmark group of companies. They are called the Overlap Portfolio Specialization Index and the Portfolio Specialization Index. They are defined in the following manner.

Overlap Portfolio Specialization Index of Company j = $OPSI_j$ = $\Sigma_k\ w_k\ RSI_k$

with k = 1 … N the number of IPC-classes in which company j overlaps with the IPC-classes of the Flemish target company

with RSI_k the Relative Technological Specialization Index of company j in IPC-class k

with w_k the relative weight of IPC-class k in the overlapping part of the patent portfolio of company j with the Flemish target company. Thus w_k is the fraction of the total number of patents in IPC-class k viz. the total number of patents across all overlapping IPC-classes in the comparison with a specific Flemish target company.

(hence, if company j has a total of 1000 patents in its portfolio, of which "only" 100 in overlapping IPC-classes, then the weight will be fractioned against the denominator of 100 and NOT of 1000 during the calculation of the Overlap Portfolio Specialization Index)

Thus, the Overlap Portfolio Specialization Index is a weighted specialization index, showing the relative position of each of the benchmark companies viz. a target Flemish company, but limited to the IPC-classes or technological domains in which this target company has developed its own portfolio.

In other words, whenever the OPSI-value of a benchmark company is lower than the PSI of a Flemish target company, this means that the benchmark company is lagging behind the Flemish target at least in the technological domains of the Flemish target. If on the other hand the OPSI-value of a benchmark company is higher than the PSI-value of the Flemish target, then this points to a relative advantage of the benchmark company over the target company. As a consequence, the OPSI-PSI comparison allows for an analysis of the relative strengths and weaknesses of a group of Flemish target companies viz. their most important European competitors. Of course, the target companies and entities are to be chosen by the researcher or analyst, depending upon the portfolio analysis she or he intends to conduct. Depending on the choice of target entities, the relevant benchmark group can then be formed.

As stated, though, the benchmark companies or entities will also be active in IPC-classes that differ from the ones overlapping with the target company or entity. Hence the need to compute a second Portfolio Specialization Index for each of the benchmark companies or entities. This second Index simply is the total weighted Portfolio Specialization Index computed across all IPC-classes in which the benchmark company is active.

Portfolio Specialization Index of Benchmark Company j = PSI_j = $\Sigma_k\ w_k\ RSI_k$

with k = 1 … N the number of IPC-classes in which company j (j = 1 … 665 in our example) is active

with RSI_k the Relative Technological Specialization Index of company j in IPC-class k

with w_k the relative weight of IPC-class k in the total patent portfolio of company j. Thus, w_k is the fraction of the total number of patents in IPC-class k.

Step 3

Based on these computations, the following positioning map can now be derived. First of all, for each company, a transformed PSI and OPSI is now computed according to the formula:

$$100 \times (Index^2-1/Index^2+1)$$

This leads to new indices with values between -100 and +100, with 0 as a neutral value (note: in the original PSI and OPSI indices, 1 is the neutral value). This step then leads to four quadrants viz. a particular target company or entity in which the benchmark group of companies or entities is to be found. The quadrant W/W combines all companies that underperform the target company, as well for the overlap part of their portfolio as for the total portfolio. The quadrant S/S combines all companies that outperform the target company, as well for the overlap part of their portfolio as for the total portfolio. The quadrants S/W and W/S combine the benchmark companies that underperform or outperform the target company on one of both indices. This then leads to the following benchmark mapping tool:

Positioning Target "XXX" Viz. EPO-benchmarks	**Companies that are weaker in the overlap part of their portfolio**	**Companies that are stronger in the overlap part of their portfolio**
Companies that are stronger in their portfolio	**W/S**	**S/S**
Companies that are weaker in their portfolio	**W/W**	**S/W**

V. Empirical application of patent-based portfolio mapping

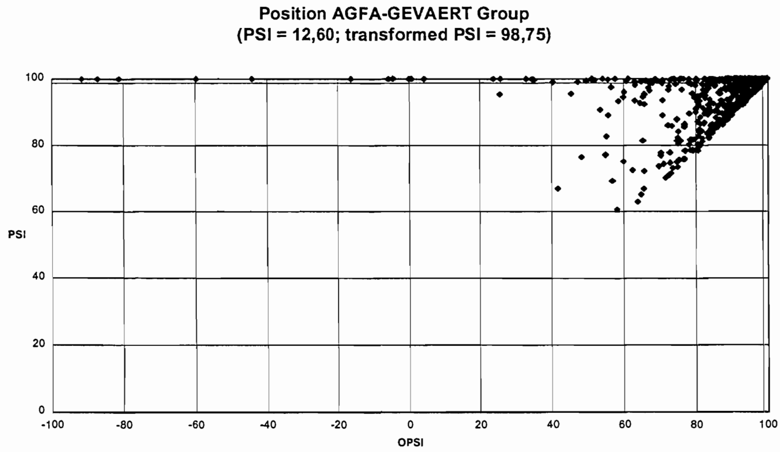
We have applied the aforementioned methodology for S&T portfolio benchmarking to the top-20 companies in Belgium and Flanders in terms of their patent strength. As mentioned, these companies account for more than 60% of the total EPO-patent population in Flanders for the period 1978-1996. The companies were benchmarked against their 665 peers in the EPO patent database that reported a cumulative number of patents in their portfolio over the time period considered, which was in excess of 50. For the Flemish and Belgian target companies as well as for the benchmark companies, the PSI and OPSI indices were computed as described in the previous paragraph. This computation has led to Excel-spreadsheets like the one reported below.

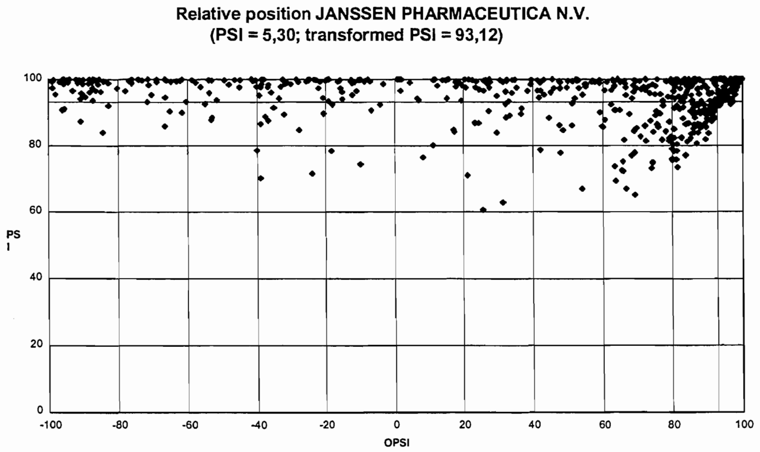
Benchmark/Target	Solvay OPSI	Solvay PSI	Alcatel OPSI	Alcatel PSI
GEC ALSTHOM Groep	86,135082014	99,635533458	74,218166711	99,635533458
GEC-MARCONI LIMITED	83,499562917	89,296449847	76,805056079	89,296449847
GENENTECH, INC.	86,120279062	99,340535723	99,344944322	99,340535723
GENERAL ELECTRIC Groep	75,414194635	75,578096048	72,842764451	75,578096048
GENERAL FOODS CORPORATION	73,590632547	99,970727721	99,972175471	99,970727721
GENERAL MOTORS CORPORATION	84,100545403	93,666171013	87,338215833	93,666171013
GENERAL SIGNAL CORPORATION	95,254858703	95,804916679	88,804916364	95,804916679

Based on these computations, we can now map the relative position of the S&T portfolio of each of the companies against the benchmark control group. In Figure 3, the results for two of the major Flemish companies, Agfa (a photochemical company) and Janssen Pharmaceutica (a pharmaceutical company) are shown.

Both maps show a strong relative position of the two companies viz. the control group of benchmarks, both in absolute terms and in terms of the overlap zone. Of course, these analyses can now be refined to examine and to cover specific subsets of the benchmark control group in order to refine the relative position analysis. This step is easy to do since it only requires zooming in on specific areas of the S&T portfolio map.

Figure 3: S&T Portfolio Benchmarks for 2 Major Flemish Companies





VI. Conclusion

In this paper, we have demonstrated the use of patent data to monitor science and technology (S&T) portfolios. As S&T portfolios have become instrumental in examining and monitoring the vitality of both institutions and regions in the innovation game that underpins their economic growth and development, the development of portfolio benchmark tools and instruments should receive ample attention. As argued, those portfolios have to be monitored not only at the intra-organisational level, but also at the inter-organizational level and at the levels of specific systems of innovation. Therefore, the development of appropriate, easy-to-use and transparant, benchmark indicators to assess the strengths and weaknesses of inter-organizational S&T portfolios is tantamount. This has been the objective of the computational mapping described and developed in this paper.

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